Application of a New Technique for Human Event Analysis (ATHEANA) at a Pressurized-Water Reactor*

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1 Introduction

Over the past several years, the U.S. Nuclear Regulatory Commission (NRC) has sponsored the development of a new method for performing human reliability analyses (HRAs). A major impetus for the program was the recognized need for a method that would not only address errors of omission (EOOs), but also errors of commission (EOCs). Although several documents have been issued describing the basis and development of the new method referred to as A Technique for Human Event Analysis (ATHEANA) [1, 2, and 3], two documents were drafted to initially provide the necessary documentation for applying the method: the frame-of-reference (FOR) manual, which served as the technical basis document for the method and the implementation guideline (IG), which provided step-by-step guidance for applying the method. (These two documents are now integrated into Draft NUREG-1624 [4]). Together, the two documents presented the information needed to identify, characterize, quantify, and integrate into probabilistic risk assessment (PRA) models, potential human failure events (HFEs), unsafe actions (UAs), and their error-forcing contexts (EFCs). HFEs, UAs, and EFCs are critical elements of the ATHEANA method and are defined as follows:

- HFE — A basic event that is modeled in the logic models of a PRA (event and fault trees) and that represents a failure of a function, a system, or a component that is the result of one or more unsafe actions. An HFE reflects the PRA systems modeling perspective.
- UA — An action inappropriately taken, or not taken when needed, by plant personnel that results in a degraded plant safety condition.
- EFC — The situation that arises when particular combinations of performance shaping factors (PSFs) and plant conditions create an environment in which unsafe actions are more likely to occur.

Upon the completion of the draft FOR manual and the draft IG in April 1997, along with several "step-throughs" of the process by the development team, the method was ready for a third-party test. The method was demonstrated at Seabrook Station in July 1997.

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The main goals of the demonstration were to (1) test the ATHEANA process as described in the FOR manual and the IG, (2) test a training package developed for the method, (3) test the hypothesis that plant operators and trainers have significant insight into the EFCs that can make UAs more likely, and (4) identify ways to improve the method and its documentation.

A set of criteria to evaluate the "success" of the ATHEANA method was identified as follows: (1) the FOR manual and the IG "work" if (a) the documentation is understandable, and (b) the process is usable; (2) training is effective if (a) it motivates the team, (b) it facilitates the use of the FOR manual and the IG, and (c) it enables the leader to direct the team; (3) the process identifies demanding scenarios involving EOCs if (a) plant operators judge the scenarios to be "demanding," (b) the plant staff identifies and implements "fixes" for some scenarios, and (c) the plant staff believes that ATHEANA can or will identify important problems; and (4) users identify improvements in ATHEANA tools and processes.

The results of the Seabrook demonstration are evaluated against the success criteria, and important findings and recommendations regarding ATHEANA that were obtained from the demonstration are presented below in Section 3. A discussion of the EFCs, UAs, and HFEs identified during the demonstration and their quantification are discussed in a companion paper presented in these proceedings [5]. A detailed discussion of all aspects of the demonstration can be found in Appendix A of Draft NUREG-1624 [4].

2 Demonstration Process

The first demonstration of ATHEANA began with a 3-day training session provided by the ATHEANA development team. The demonstration was scheduled to take place over a 20-week period, with most of the actual analysis occurring during six team meetings held at Seabrook. The licensee supported the analysis with two individuals from its PRA staff and two from its training staff. Both individuals from training were licensed operators, and one of them was a senior reactor operator (SRO) "on shift" until a few months before the demonstration. The licensee also provided an operating crew to test an accident scenario on the simulator, and the demonstration team was also allowed to view several scheduled training exercises on the simulator. A PRA expert, with experience in HRA (not ATHEANA), from Sandia National Laboratories was the demonstration team leader. Consulting and documentation support on the application of the method was provided by members of the ATHEANA development team. After the initial training session and as the demonstration progressed, supplemental training was provided on several important aspects of the method, including the process for identifying and deriving potential EFCs that could lead to UAs, debriefing operators after simulator exercises to obtain EFC and UA-related information, and quantifcation of EFCs and UAs.

3 Findings and Recommendations From the Demonstration

The Seabrook demonstration produced significant information on the ATHEANA method. To delineate this information and some of the lessons learned, the method is evaluated against the goals of the demonstration and the success criteria previously identified in Section 1.

3.1 Did the FOR Manual and the IG "Work"?

Although needed improvements were identified in some of the guidance and support information contained in the FOR manual, the IG and the process documentation tables, the basic search process for HFEs, UAs, and EFCs generally worked well. The most difficult aspect of the search process was the identification of the human contribution to the EFC. That is, the demonstration team was able to use the documentation in the FOR manual and the IG to identify potential HFEs, UAs, and the plant side of the EFC but had more difficulty using the guidance on psychological and human factors to evaluate how operators could believe that a UA is the right thing to do. After initial attempts at this part of the ATHEANA process, a supplemental training session was provided to the demonstration team on how to use the documentation in the FOR manual and the IG to address the human contribution. Although the additional training was successful in that the team was able to identify potential human-related EFCs, several ways were still identified to improve this part of the process.

From the perspective of the demonstration team (as determined from discussions and the results of the questionnaires), the main problem with the FOR manual and the IG (and the method itself) was that the overall process was thought to be cumbersome and very labor and resource intensive. As previously noted, at least part of the problem is related to the limitations identified with the search process and the tables that were used to document the search process. These aspects of the process are being improved and it should be possible to significantly improve the efficiency of the process through computerization and human factoring of the application of the method. The first application of ATHEANA may also have seemed cumbersome because the process was being evaluated and modified while it was being used. However, the application of ATHEANA will always be demanding to some extent. ATHEANA was designed to identify the types of events that could lead to serious consequences that have not been previously identified. That is, the approach is derived from a characterization of serious accidents that have occurred in the nuclear and other industries in the past, and it is clear that identifying such events will never be trivial. The most effective use of ATHEANA will come from a careful prioritization of the areas to be analyzed (so that available resources are allocated to the most critical areas) and a willingness to continue examining a plant over the long term in order to eventually cover most potential human error scenarios.

The notion of careful prioritization points to another aspect of the ATHEANA process that needs to be improved in the future. During the demonstration, it was discovered that

a careful characterization of plant operations and the general strategies used by plant crews to ensure successful response to accident scenarios can enhance the ability of the analysts to establish search priorities and limit initial efforts to those contexts that are most likely to create significant problems. Such characterizations will also assist analysts in identifying the more likely PSFs that will contribute to a particular EFC. The lesson learned about the need to characterize the way in which plant crews operate was obtained primarily from the development team's observation of simulator exercises. In fact, the importance of simulator exercises to the application of the ATHEANA method was brought to the fore during the Seabrook demonstration. Section A.7.2 of Draft NUREG-1624 [4] provides more detailed discussions of the important methodological findings derived from simulator exercises conducted at Seabrook Station. Also, other specific planned improvements in the process (the IG and the FOR manual) can be found in Section 7 of Draft NUREG-1624 [4].

3.2 Was the Training Effective?

Survey comments (obtained immediately after the initial training) from the Seabrook personnel who participated in the training were very positive about the overall training package. Some important suggestions for improvements included a more extensive initial overview of the method directed at plant management and a brief review of PRA for the benefit of trainers and operators who need a refresher course. It was also suggested that detailed training for later steps in the process, such as quantification, be presented just before the beginning of that step. As previously noted in Section 2, supplemental training was provided just before the quantification process and in conjunction with the identification of potential EFCs.

After the demonstration was completed, four of the five team members responded to an additional survey on the adequacy and effectiveness of the training. There was general consensus that the training created an interest in the ATHEANA process and motivated the team to search for risk-significant events. It was also agreed that the training did facilitate the use of the FOR manual and the IG, and that this training was very critical. In fact, the team thought that the ATHEANA process as currently developed is very complex and that the "method appears to need more than the written materials to understand and explain it." This finding suggests that training on the use of the method may be needed by most users before beginning an application. The need for training is certainly related to the fact that the documentation for ATHEANA is, and will be, fairly extensive. The need for extensive documentation is due to the complexity of the process required to isolate potentially significant human failure events. In particular, the need for analysts (who often are engineers) to understand the basic psychological concepts and models underlying ATHEANA requires a detailed tutorial. Nevertheless, with the improvements identified from the demonstration for the FOR and the IG, the sense of complexity may be lessened.

The questionnaires also indicated that the team leader needs to be very knowledgeable about the application of the method in order to avoid "inappropriately allocating time resources" on the different steps of the method. The apparent implication of this comment was that until the method is known well, too much energy (or too little) may

be focused on a particular step at the wrong time. Other comments from the questionnaires indicated that the demonstration team thought the training did help the team leader. The team leader was relied upon for guidance and he "kept them on track."

3.3 Did the Process Identify Demanding Scenarios Involving EOCs?

This criterion was addressed primarily by asking the following questions: (1) Did the plant operators judge the identified scenarios as cognitively demanding and did they contain EOCs, (2) did the plant staff identify and implement "fixes" for some of the scenarios identified, and (3) does the plant staff believe that ATHEANA can or will identify important problems?

As discussed in the paper on the results of the quantification process presented in these proceedings [5], the identified scenarios contained both EOOs and EOCs. Moreover, the plant operators did judge the scenarios to be demanding. The operators on the team and those polled felt that given the occurrence of the identified EFCs for the scenarios examined, there was a high probability that the identified UAs would occur. Thus, the identified scenarios were perceived as being demanding. However, the scenarios identified during the Seabrook demonstration also had a high probability of being recovered, and the probabilities of the EFCs were determined to be low. Nevertheless, it is clear that the ATHEANA methodology provides the tools that will allow users to identify demanding scenarios in their plant. Given that a major goal of the method is to identify situations that can lead to serious accidents, it is not necessarily surprising that the events identified in this case had generally low probabilities (if serious accidents are to have low probabilities).

Although there was substantial evidence that the plant staff believes that ATHEANA is useful and that it can identify important problems (see Section A.7 of Draft NUREG-1624), it should also be noted that the plant staff was very concerned about the usefulness of the method relative to the resources required. They were also concerned about the ability to be thorough with the method, that is, the ability to identify all (or even most) potential human error scenarios. As previously discussed in Section 3.1, it is true that ATHEANA will require significant resources and that thoroughness will not necessarily be ensured. However, steps are being taken to improve the efficiency of the method and, after observing the application of the method at Seabrook, it is thought that the resource demands will be best represented by a negatively accelerating function. That is, as additional scenarios are examined, the information gained from analyzing the previous scenarios will make the later analyses much more efficient. This "savings" will not only be due to increased familiarity with the method, but will also be related to the fact that much of what is identified in one set of scenarios can be used in others. Thus, the method capitalizes on redundancy in the functions relevant to responding to the set of initiators and in their related sequences, and in the knowledge gained about how to think about and identify HFEs, UAs, and EFCs.

3.4 Did the Users Suggest Improvements in the ATHEANA Process and Tools?

Many of the suggested improvements to ATHEANA made by the users were previously discussed. In particular, the need for improved documentation tables (which underwent many changes as the demonstration proceeded) and clearer ties between the search process in the IG and the supporting tables in the FOR manual were cited. Another frequent suggestion was that the process and its documentation be computerized to make application of ATHEANA more efficient.

4 Conclusion

All of the goals and criteria for success of the method and the demonstration were essentially met, including identifying several needed improvements in the ATHEANA tools and processes. Moreover, in addition to the lessons learned previously described, other important methodological findings were identified during the demonstration that could not be discussed in this paper because of space limitations. In particular, findings related to the use of simulator exercises in the application of ATHEANA were particularly interesting. The reader is encouraged to see Section A.7 in NUREG-1624 [4] for a discussion of the use of simulators in the application of ATHEANA.

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